DESIGN AND DEVELOPMENT OF LOW-COST FRICTION STIR WELDING

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To my beloved father **Dr. Zakaria Bin Haji Kassim**

To my beloved mother **Sharifah Binti Haji Idris**

To my beloved sisters **Datin Shazelina Binti Zakaria** and **Haslinda Binti Zakaria**

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In the name of Allah, the most Gracious and most Compassionate

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ABSTRACT

The purpose of this study is to design and develop a friction stir welding (FSW) based on current CNC machine. The development is based on CNC milling machine using FSW tool that been machined. Aluminium Alloy 5083 was used as workpiece sample while mild steel was selected as the material for the tool. The experiments are based on selected welding conditions such as feed speed, tool rotation speed, plunge depth and tool design. Some of the parameter was set to a certain value, thus leaving 3 parameters with different value. For analyzation, feed speed and tool rotation was concentrated to study which parameter is the best based on analysis, either the combination of 10, 15 and 20 mm/min feed speed and tool rotation of 1000, 1500 and 2000 rpm. Post analysis involving hardness test, impact test and microstructure analysis. The experimental results were statistically analyzed to study the influence of both parameters on weld area cross section. Based on hardness test and impact test, the weld area are strong enough after combining two aluminum. The microstructural imaging shows that at certain number of feed speed or rotation speed, the weld area starting to crack. The outcome of this study shows that feed speed and tool rotation speed have significance effects on the strength and cosmetic of weld area and the best condition is at 10 mm/min feed speed and 1000 rpm of tool rotation speed. The results also shows that the setting of the experiment can have bigger effect on the welding result.

ABSTRAK

Tujuan kertas penyelidikan ini dijalankan adalah untuk merekabentuk dan membangunkan kimpalan geseran kacau (FSW) berdasarkan pada mesin CNC yang terkini. Pembangunan ini adalah berdasarkan pada mesin "*milling*" CNC menggunakan alat FSW yang telah dimesin. Aluminium Alloy 5083 telah digunakan sebagai sampel bahan kerja manakala "*mild* steel" telah dipilih sebagai bahan untuk alat. Eksperimen berdasarkan keadaan kimpalan terpilih seperti kelajuan halaan, alat kelajuan putaran, kedalaman tolakan bawah dan reka bentuk alat. Ada di antara parameter yang telah ditetapkan kepada nilai tertentu, sekali gus meninggalkan 3 parameter dengan nilai yang berbeza. Untuk analisis, kelajuan halaan dan putaran alat adalah tertumpu untuk mengkaji parameter yang terbaik berdasarkan analisis, sama ada gabungan 10, 15 dan 20 mm / min kelajuan halaan dan putaran alat 1000, 1500 dan 2000 rpm. Analisis selepas eksperimen melibatkan ujian kekerasan, ujian hentaman dan analisis mikrostruktur. Keputusan eksperimen telah dianalisis secara statistik untuk mengkaji pengaruh kedua-dua parameter pada keratan rentas kawasan kimpalan. Berdasarkan ujian kekerasan dan ujian kesan, kawasan kimpalan cukup kuat selepas menggabungkan dua aluminium. Pengimejan mikrostruktur menunjukkan bahawa pada sebilangan kelajuan suapan atau kelajuan putaran, kawasan kimpalan mula retak. Hasil kajian ini menunjukkan bahawa kelajuan halaan dan alat kelajuan putaran mempunyai kesan signifikan kepada kekuatan dan kosmetik kawasan kimpalan dan keadaan yang terbaik adalah pada 10 mm / min kelajuan halaan dan 1000 rpm kelajuan putaran alat. Keputusan juga menunjukkan bahawa penetapan eksperimen boleh mempunyai kesan yang lebih besar ke atas hasil kimpalan.

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i	Material Safety Data Sheet	MSDS
ii	Computer Numerical Control	CNC
iii	Revolution Per Minute	RPM
iv	Analysis of Variance	ANOVA
v	Machine Condition Monitoring	MCM
vi	Surface Roughness	Ra
vii	Design of Experiment	DOE
viii	Friction Stir Welding	FSW

CHAPTER 1

INTRODUCTION

1.1 Background

Joining two or more materials become one of essential processes in machinery industry. Since centuries and decades ago, these processes of joining materials become a norm to produce a better and more flexible shape for easy usage. One material can be join with similar or different and suitable material. Nail and hammer is the most basic tool to combine the materials but have a lot of limitations such as material hardness, accuracy, number of product to be produced and product durability.

Joining between two metals are generally categorize from metal fabrication. Chart below detailing the joint process categorization, from permanent and nonpermanent category to further level of subcategory. One of the process often used in industry are from solid state category.

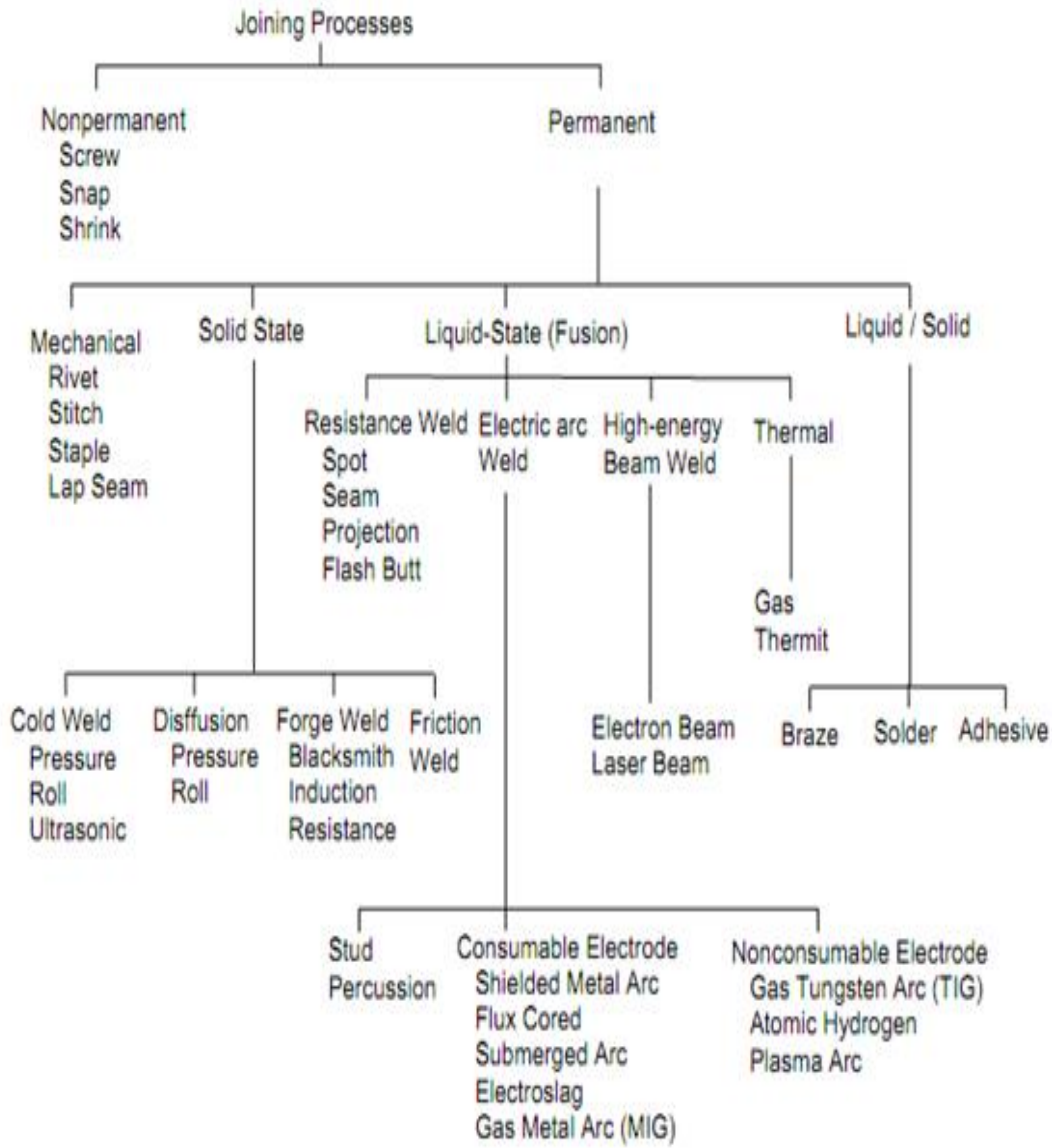

Figure 1.1: Chart tree of joining process category

Metal fabrication is a value added process that involves the construction of machines and structures from various raw materials. A fab shop will bid on a job, usually based on the engineering drawings, and if awarded the contract will build the product. Large fab shops will employ a multitude of value added processes in one plant or facility including welding, cutting, forming and machining. These large fab shops offer additional value to their customers by limiting the need for purchasing personnel to locate multiple vendors for different services. Metal fabrication jobs usually start with shop drawings including precise measurements then move to the fabrication stage and finally to the installation of the final project. Fabrication shops are employed by contractors, OEMs and VARs. Typical projects include; loose parts, structural frames for buildings and heavy equipment, and hand railings and stairs for buildings. Metal fabrication are divided to cutting, bending and assembly. Metal joining are from assembly category.

Assembling (joining of the pieces) is done by welding, binding with adhesives, riveting, threaded fasteners, or even yet more bending in the form of a crimped seam. Structural steel and sheet metal are the usual starting materials for fabrication, along with the welding wire, flux, and fasteners that will join the cut pieces. As with other manufacturing processes, both human labor and automation are commonly used. The product resulting from fabrication may be called a fabrication. Shops that specialize in this type of metal work are called fab shops. The end products of other common types of metalworking, such as machining, metal stamping, forging, and casting, may be similar in shape and function, but those processes are not classified as fabrication [26].

Welding is one of process of joining two or more material. Welding is a fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the workpieces and adding a filler material to form a pool of molten material (the weld pool) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld. This is in contrast with soldering and brazing, which involve melting a lower-melting-point material between the workpieces to form a bond between them, without melting the workpieces [1]. There are few process derived from the welding process with different attribute. One of it is friction welding, which used the heat from friction phenomena to melt the filler material.

Friction welding (FRW) is a solid-state welding process that generates heat through mechanical friction between workpieces in relative motion to one another, with the addition of a lateral force called "upset" to plastically displace and fuse the materials. Technically, because no melt occurs, friction welding is not actually a welding process in the traditional sense, but a forging technique. However, due to the similarities between these techniques and traditional welding, the term has become common. Friction welding is used with metals and thermoplastics in a wide variety of aviation and automotive applications.

The combination of fast joining times (on the order of a few seconds), and direct heat input at the weld interface, yields relatively small heat-affected zones. Friction welding techniques are generally melt-free, which avoids grain growth in engineered materials, such as high-strength heat-treated steels. Another advantage is that the motion tends to "clean" the surface between the materials being welded, which means they can be joined with less preparation. During the welding process, depending on the method being used, small pieces of the plastic or metal will be forced out of the working mass (flash). It is believed that the flash carries away debris and dirt.

Another advantage of friction welding is that it allows dissimilar materials to be joined. This is particularly useful in aerospace, where it is used to join lightweight aluminum stock to high-strength steels. Normally the wide difference in melting points of the two materials would make it impossible to weld using traditional techniques, and would require some sort of mechanical connection. Friction welding provides a "full strength" bond with no additional weight. Other common uses for these sorts of bi-metal joins is in the nuclear industry, where copper-steel joints are common in the reactor cooling systems; and in the transport of cryogenic fluids, where friction welding has been used to join aluminum alloys to stainless steels and high-nickel-alloy materials for cryogenic-fluid piping and containment vessels.

Friction welding is also used with thermoplastics, which act in a fashion analogous to metals under heat and pressure. The heat and pressure used on these materials is much lower than metals, but the technique can be used to join metals to plastics with the metal interface being machined. For instance, the technique can be used to join eyeglass frames to the pins in their hinges. The lower energies and pressures used allows for a wider variety of techniques to be used [27].

Friction-stir welding (FSW) is a solid-state joining process (the metal is not melted) that uses a third body tool to join two faying surfaces. Heat is generated between the tool and material which leads to a very soft region near the FSW tool. It then mechanically intermixes the two pieces of metal at the place of the join, then the softened metal (due to the elevated temperature) can be joined using mechanical pressure (which is applied by the tool), much like joining clay, or dough. It is primarily used on aluminum, and most often on extruded aluminum (non-heat treatable alloys), and on structures which need superior weld strength without a post weld heat treatment [2].

There are few factors of why not many using FSW in their factories. One of the reason is high cost involving owning and setup the machine. However, FSW machine can be designed and developed from other machining process for purpose of it capable of welding materials. With different setup and parameters, achieving this is not impossible.

1.2 Problem Statement

FSW is one of the most recommended and used choice of joining metals in industry. Top companies used FSW in producing their own product. For example, tech giant Apple used FSW to produce its line of computer product. Other example is the production of fast train in Japan. However, one of the downside of using FSW is the cost of owning, using and maintaining a dedicated FSW machine.

For factories that are small or having limited space, having a dedicated machine to do the process are not recommended unless the machine are maximize its utilization. This is because, it is less productive to keep an underutilize FSW machine in production space. It is rather productive to place an additional production machine in line instead.

Owning a FSW machine does not only consume some space but also dishing out an additional cost for obtaining the machine. Other than buying the machine, the maintenance cost for the machine need to be in consideration. In Malaysia, the FSW process are quite new to our engineers and technical personnel. Therefore, training course to operate the FSW dedicated machine need to be provided to the technical workers including operators. Thus, another cost to be considered to supply the course needed.

Having a machine that may not always on use could be unwise. Instead of buying the machine, FSW can be developed by redesign another machine by adjusting its parameters and settings.

1.3 Objective

To design and fabricate or modify an existing CNC milling drilling machine to perform as a friction welding machine suitable for experimental and basic research activities.

1.4 Scope

1. To carry out in-depth study on the friction stir welding process – steps, parameters, machines and applications.
2. To carry out in-depth study on the CNC milling machine structure and modification related issues.
3. To carry out modification/fabrication of the machines.
4. To perform basic performance test of the machine.

1.5 Significant of Study

After fulfilling the project scope and methodology, fabricating a friction stir welding machine by redesign a milling machine can be achieved. Achieving this feat not only giving the alternative process for joining two or more materials, but also prevent additional cost by having milling machine to do welding process apart of its usual milling process.

This study can be expanded further with design and development of friction stir welding using various machines like turning.

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